DSN Functions and Facilities

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The objectives, functions, and organization of the Deep Space Network are summarized. The Deep Space Instrumentation Facility, the Ground Communications Facility, and the Space Flight Operations Facility are described.

The Deep Space Network (DSN), established by the NASA Office of Tracking and Data Acquisition under the system management and technical direction of JPL, is designed for two-way communications with unmanned spacecraft traveling approximately 16,000 km (10,000 mi) from Earth to planetary distances. It supports, or has supported, the following NASA deep space exploration projects: *Ranger, Surveyor, Mariner* Venus 1962, *Mariner* Mars 1964, *Mariner* Venus 67, *Mariner* Mars 1969, *Mariner* Mars 1971 (JPL); *Lunar Orbiter* and *Viking* (Langley Research Center); *Pioneer* (Ames Research Center); *Helios* (West Germany); and *Apollo* (Manned Spacecraft Center), to supplement the Manned Space Flight Network (MSFN).

The Deep Space Network is one of two NASA networks. The other, known as the Spaceflight Tracking and Data Network, is under the system management and technical direction of the Goddard Space Flight Center. Its function is to support manned and unmanned Earth-orbiting and lunar scientific and communications satellites. Although the DSN was concerned with unmanned lunar spacecraft in its early years, its primary objective now and into the future is to continue its support of planetary and interplanetary flight projects. It has been a development objective that the network capability be kept at the state of the art of telecommunications and data handling and that it support as many flight projects as possible with a minimum of mission-dependent hardware and software. It provides direct support of each project through that project's tracking and data system. This management element, in concert with the telecommunications and mission operations personnel of the project, is responsible for the design and operation of the hardware and software which are required for the conduct of flight operation. The organization and procedures necessary to carry out these activities are described in Ref. 1.

The DSN function, in supporting a flight project by tracking the spacecraft, is characterized by six DSN systems:

(1) DSN Tracking System. Generates radio metric data; i.e., angles, one- and two-way doppler and range.

(2) DSN Telemetry System. Receives, records, and retransmits engineering and scientific data generated in the spacecraft.

(3) DSN Command System. Sends coded signals to the spacecraft in order to initiate spacecraft functions in flight.

(4) DSN Monitor System. Instruments, transmits, records, and displays those parameters of the DSN that measure its performance.

(5) DSN Simulation System. Provides computer-based facilities in order to test and train network functions and assist the flight project in carrying out similar functions for its Mission Operations System.

(6) DSN Operations Control. Provides the hardware and software, personnel, real-time and non-real-time operational direction of the network, and primary interface with the flight projects Mission Operations personnel.

The facilities needed to carry out these functions have evolved in three technical areas: (1) the deep space stations and the telecommunications interface through the RF link with the spacecraft is known as the Deep Space Instrumentation Facility (DSIF); (2) the Earth-based point-to-point voice and data communications from the stations to the control center is known as the Ground Communications Facility (GCF); (3) the control center, both for network control function and mission control support, is known as the Space Flight Operations Facility (SFOF).

I. Deep Space Instrumentation Facility

A. Tracking and Data Acquisition Facilities

A world-wide set of deep space stations (DSSs) with large antennas, low-noise phase-lock receiving systems, and high-power transmitters provide radio communications with spacecraft. The DSSs and the deep space communications complexes (DSCCs) they comprise are given in Table 1.

Radio contact with a spacecraft usually begins when the spacecraft is on the launch vehicle at Cape Kennedy, and it is maintained throughout the mission. The early part of the trajectory is covered by selected network stations of the Air Force Eastern Test Range (AFETR) and the MSFN of the Goddard Space Flight Center,[1] Normally, two-way communications are established between the spacecraft and the DSN within 30 min after the spacecraft has been injected into lunar, planetary, or interplanetary flight. A compatibility test station at Cape Kennedy (discussed later) monitors the spacecraft continuously during the launch phase until it passes over the local horizon. The deep space phase begins with acquisition by either DSS 51, 41, or 42. These and the remaining DSSs given in Table 1 provide radio communications to the end of the flight.

To enable continuous radio contact with spacecraft, the DSSs are located approximately 120 deg apart in longitude; thus, a spacecraft in deep space flight is always within the field-of-view of at least one DSS, and for several hours each day may be seen by two DSSs. Furthermore, since most spacecraft on deep space missions travel within 30 deg of the equatorial plane, the DSSs are located within latitudes of 45 deg north or south of the equator. All DSSs operate at S-band frequencies: 2110–2120 MHz for Earth-to-spacecraft transmission and 2290–2300 MHz for spacecraft-to-Earth transmission.

To provide sufficient tracking capability to enable useful data returns from around the planets and from the edge of the solar system, a 64-m (210-ft) diam antenna network will be required. Two additional 64-m (210-ft) diam antenna DSSs are under construction at Madrid and Canberra, which will operate in conjunction with DSS 14 to provide this capability. These stations are scheduled to be operational by the middle of 1973.

B. Compatibility Test Facilities

In 1959, a mobile L-band compatibility test station was established at Cape Kennedy to verify flight–spacecraft–DSN compatibility prior to the launch of the *Ranger* and *Mariner* Venus 1962 spacecraft. Experience revealed the need for a permanent facility at Cape Kennedy for this function. An S-band compatibility test station with a 1.2-m (4-ft) diam antenna became operational in 1965. In addition to supporting the preflight compatibility tests, this station monitors the spacecraft continuously during the launch phase until it passes over the local horizon.

Spacecraft telecommunications compatibility in the design and prototype development phases was formerly verified by tests at the Goldstone DSCC. To provide a more economical means for conducting such work and because of the increasing use of multiple-mission telemetry and command equipment by the DSN, a compatibility test area (CTA) was established at JPL in 1968. In all essential characteristics, the configuration of this facility is identical to that of the 26-m (85-ft) and 64-m (210-ft) diam antenna stations.

The JPL CTA is used during spacecraft system tests to establish the compatibility with the DSN of the proof test

[1]The 9-m (30-ft) diam antenna station established by the DSN on Ascension Island during 1965 to act in conjunction with the MSFN orbital support 9-m (30-ft) diam antenna station was transferred to the MSFN in July 1968.

model and development models of spacecraft, and the Cape Kennedy compatibility test station is used for final flight spacecraft compatibility validation testing prior to launch.

II. Ground Communications Facility

The GCF provides voice, high-speed data, wideband data, and teletype communications between the SFOF and the DSSs. In providing these capabilities, the GCF uses the facilities of the worldwide NASA Communications Network (NASCOM)[2] for all long distance circuits, except those between the SFOF and the Goldstone DSCC. Communications between the Goldstone DSCC and the SFOF are provided by a microwave link directly leased by the DSN from a common carrier.

Early missions were supported by voice and teletype circuits only, but increased data rates necessitated the use of high-speed circuits for all DSSs, plus wideband circuits for some stations.

[2]Managed and directed by the Goddard Space Flight Center.

III. Space Flight Operations Facility

Network and mission control functions are performed at the SFOF at JPL. The SFOF receives data from all DSSs and processes that information required by the flight project to conduct mission operations. The following functions are carried out: (1) real-time processing and display of radio metric data; (2) real-time and non-real-time processing and display of telemetry data; (3) simulation of flight operations; (4) near-real-time evaluation of DSN performance; (5) operations control, and status and operational data display; and (6) general support such as internal communications by telephone, intercom, public address, closed-circuit TV, documentation, and reproduction of data packages. Master data records of science data received from spacecraft are generated. Technical areas are provided for flight project personnel who analyze spacecraft performance, trajectories, and generation of commands.

Reference

1. *The Deep Space Network*, Space Programs Summary 37-50, Vol. II, pp. 15–17. Jet Propulsion Laboratory, Pasadena, Calif., Mar. 31, 1968.

Table 1. Tracking and data acquisition stations of the DSN

DSCC	Location	DSS	DSS serial designation	Antenna		Year of initial operation
				Diameter, m (ft)	Type of mounting	
Goldstone	California	Pioneer	11	26 (85)	Polar	1958
		Echo	12	26 (85)	Polar	1962
		(Venus)[a]	13	26 (85)	Az-El	1962
		Mars	14	64 (210)	Az-El	1966
—	Australia	Woomera	41	26 (85)	Polar	1960
Tidbinbilla	Australia	Weemala (formerly Tidbinbilla)	42	26 (85)	Polar	1965
		Ballima (formerly Booroomba)	43	64 (210)	Az-El	Under construction
—	South Africa	Johannesburg	51	26 (85)	Polar	1961
Madrid	Spain	Robledo	61	26 (85)	Polar	1965
		Cebreros	62	26 (85)	Polar	1967
		Robledo	63	64 (210)	Az-El	Under construction

[a]A research-and-development facility used to demonstrate the feasibility of new equipment and methods to be integrated into the operational network. Besides the 26-m (85-ft) diam az–el-mounted antenna, DSS 13 has a 9-m (30-ft) diam az–el-mounted antenna that is used for testing the design of new equipment and support of ground-based radio science.